Shoemaker-Levy 9/Jupiter Collision to be Observed at ESO

The upcoming collision between comet Shoemaker-Levy 9 and giant planet Jupiter has led to intensive preparations by astronomers all over the world and it is obvious that this unique event has also caught the imagination of the public. According to the latest calculations the impacts will commence in the evening of July 16 and end in the morning of July 22, 1994. There will be no less than 12 different investigations at the ESO La Silla observatory during this period.

A Unique Event

This is the first time ever that it has been possible to predict such a collision. Although it is difficult to make accurate estimates, it is likely that there will be important, observable effects in the Jovian atmosphere.

High-resolution Hubble Space Telescope images have shown that the comet has broken up into 21 or more individual fragments (termed "nuclei"), whose diameters probably range between a few kilometres and a few hundred meters. There is also much cometary dust visible around the nuclei; it is probably a mixture of grains of different sizes, from sub-millimetre sand up to metre-sized boulders. No outgassing has so far been observed from Shoemaker-Levy 9, but this is not unusual for a comet at a heliocentric distance of 5 A.U.

Accurate determinations of the positions of the individual nuclei have permitted to calculate quite precise orbits and it is certain that all of them will indeed collide with Jupiter. The points of impact are in the Jovian southern hemisphere, at $\sim -45°$ latitude. Unfortunately, these impacts will happen just behind Jupiter's limb, i.e., out of sight from the Earth. However, due to the rapid rotation of the planet, the impact sites will come into view only ~10–20 minutes later at the very limb, where they will be seen "from the side". It is also fortunate that the American spacecraft Galileo, now approaching Jupiter, will have a direct view of the impact sites.

On the basis of the recent astrometric observations, including some with the Danish 1.5-m telescope at La Silla, the impact times can now (June 20) be predicted to about ± 30 minutes (2σ). The first, rather small nucleus ("A") will hit the upper layers of Jupiter's atmosphere on July 16, 1994 at about 20^h (UT); the apparently biggest nucleus ("Q") on July 20, at 20^h UT, and the last one in the train ("W"), on July 22 at about 8^h UT.

Possible Effects

The comet nuclei will hit Jupiter at a high velocity, ~60 km/sec. The correspondingly large motion energy (the "kinetic energy") will all be deposited in the Jovian atmosphere. For a 1 km fragment, this is about equal to 10^{28} erg (~250,000 Megatons).

When one of the cometary nuclei enters the upper layers of the Jovian atmosphere, it will be heated by the friction, exactly as a meteoroid in the Earth's atmosphere, and its speed will decrease very rapidly. Depending on the size of the fragment, it may evaporate completely within a few seconds, while it is still above the dense cloud layer that forms the visible "surface" of Jupiter, or it may plunge right through these clouds (and therefore out of sight) into increasingly denser, lower layers, where it ultimately comes to a complete stop and disintegrates in a giant explosion.

All of the kinetic energy is released during this process. One part will heat the surrounding atmosphere to very high temperatures; this will result in a flash of light that lasts a few seconds. Within the next minutes, a plume of hot gas will begin to rise over the impact site. It may reach an altitude of several hundred kilometres above the cloud layers and will quickly spread out in all horizontal directions.

Another part of the energy will be transformed into shock waves that will propagate into the interior of Jupiter, much as seismic waves from an earthquake do inside the Earth. When these waves again reach the upper layers of the atmosphere, they may be seen as slight increases in the local temperature along expanding circles with the impact sites at their centres (like waves in a water surface). The shock waves may also start oscillations of the entire planet, like those of a ringing bell.

During the past year, atmospheric scientists have attempted to calculate the details of these impacts, but the uncertainties are still rather large. Moreover, the magnitudes of the overall effects are entirely dependent on the energies involved, i.e., on the still not well determined sizes (masses) of the cometary nuclei.

It is also expected that there will be some kind of interaction between the cometary dust and Jupiter's strong magnetic field. The fast-moving dust grains may become electrically charged. This will possibly have a significant influence on Jupiter's radio emission and therefore be directly observable with Earth-based radio telescopes, as well as from several spacecraft, including *Ulysses*, now en route towards its first pass below the Sun. There may also be changes in the plasma torus that girdles Jupiter near the orbit of the volcanic moon Io, and some cometary dust particles may collect in Jupiter's faint ring.

All in all, this spectacular event offers a unique opportunity to study Jupiter and its atmosphere. It may also provide a first "look" into its hitherto unobservable inner regions. Nobody knows for sure, how dramatic the effects of the impacts will actually be, but unless we are prepared to observe them, we may lose a great chance that is unlikely to come back in many years, if ever.

Some Recent Developments

Both Jupiter and the cometary nuclei have been extensively observed during the past months. However, while we now possess more accurate information about the comet's motion and the times of impact, there is still great uncertainty about the effects which may actually be observed at the time of the impacts. This is first of all due to the fact that it has not been possible to measure the sizes and masses of the individual cometary nuclei and thereby to estimate the amount of energy which will be liberated at the collisions.

Despite intensive spectroscopic observations, no gas has yet been detected in any of the nuclei. We only see dust around the nuclei which are completely hidden from our view within these clouds. The amount of the dust has been steadily decreasing; this is because the dust production from the individual nuclei – which began when the parent body broke up at the time of the near-collision with Jupiter in July 1992 – is slowly diminishing with time.

Some of the smaller nuclei have recently disappeared from view, probably because they have ceased to produce dust. It is not clear, however, whether this also implies that they no longer exist at all, or whether they are just too small to be seen with available telescopes.

The Observations at ESO

In November 1993, a group of 25 cometary and planetary specialists from

Europe and the U.S.A. met at ESO to discuss possible observations from the ESO La Silla observatory in connection with the cometary impacts at Jupiter. In a resulting report, they emphasized that ESO is in a particularly advantageous situation in this respect, because the excellent site of this observatory is located in the south and Jupiter will be 12° south of the celestial equator at the time of the event and therefore well observable from here; the time available from observatories in the northern hemisphere will be much more restricted. Moreover, many different observing techniques are available at La Silla; this provides optimal conditions for effective coordination of the various programmes, in particular what concerns imaging and spectral observations in the infrared and submillimetre wavebands.

During its November 1993 meeting, the OPC granted extensive observing time for observations with the ESO telescopes of this event.

Some of the observations at ESO are aimed at the accurate determination of the positions of the individual nuclei in order to improve the determination of their orbits. By continuing this work until the very last day before the impacts, it will hopefully be possible to achieve a final timing uncertainty of a few minutes for these events. This will be of importance for all other observations, both from the ground, and especially for those carried out from the spacecraft.

A team from the Munich Observatory (Germany) under the leadership of Heinz Barwig will perform rapid brightness measurements of Jupiter's moons at the predicted times of the impacts with their special high-speed photometer attached to the ESO 1-metre telescope. The flashes from the impacts will be reflected from the surfaces of those Jupiter moons which are in view of the impact sites. If this happens when a moon is in full sunlight, the relative increase of intensity will probably only be of the order of 1 %. However, if one of the moons is located in the shadow of Jupiter and is at the same time visible from the Earth, then the relative brightening may be very conspicuous. Whether this will be the case will of course depend on the exact moments of the impacts.

Also at the time of the impacts, a group of French astronomers, headed by Bruno Sicardy of the Observatoire de Paris, will mount a special CCD camera at the Danish telescope, which will be used for different types of observations. They also hope to be able to detect some of the expected light flashes from the Jupiter moons. In addition, this programme will monitor changes in the cloud structure around the impact sites. It may also be possible to obtain low-resolution spectra which will show the temperature of the flashes, but in view of their very short duration, a few seconds at most, this will not be easy.

The same instrument will also be used by Nick Thomas of the Max-Planck-Institut für Aeronomie (Lindau, Germany) to image the Jupiter plasma torus in order to detect possible changes after the impacts.

Spectral observations of the comet have been made with the ESO 1.5-m telescope in April by Heike Rauer, also from the Max-Planck-Institut für Aeronomie. They are expected to lead to a better knowledge about the physical and chemical state of the impacting bodies. For instance, are they really so "dusty", as present observations seem to indicate, or do they contain large amounts of gas? If so, what kind of molecules are present? This will help to refine the predictions of the impact effects.

Imaging and spectral observations of the comet for the same general purposes will also be obtained in early July with the EMMI instrument at the 3.5-m New Technology Telescope by an international team headed by Rita Schulz, formerly at the University of Maryland and now at the Max-Planck-Institut für Aeronomie.

No less than 46 observing hours have been allocated at the Swedish-ESO Submillimetre Telescope (SEST) to an international group headed by Daniel Gautier, Observatoire de Paris-Meudon. During the impacts, the cometary molecules will be mixed with those in the Jovian atmosphere, some of which may come from very deep layers. Together they will be carried upwards in the plume, described above. This may provide a rare opportunity, not only to register the submillimetre emissions from those molecules which are already known to be present in the comet and on Jupiter, but also to detect new and unknown molecules otherwise not accessible for direct observations, either from the interior of the cometary nuclei or from deep down in Jupiter's enormous atmosphere.

Infrared observations will play a very important role during the ESO campaign. A new ESO-developed instrument, TIMMI (Thermal Infrared Multi-Mode Instrument) will be mounted at the ESO 3.6-m telescope and will provide detailed infrared images of the impact areas when they become visible at the limb. Two teams will be active here; one is led by Timothy A. Livengood from NASA Goddard Space Flight Center (U.S.A.) and includes several ESO staff astronomers. Thanks to the excellent imaging capabilities of TIMMI in the far-infrared spectral region, this group will be able to look far down into the atmosphere and to measure minute temperature variations. This should make it possible to register the effects of the shock-waves that arise when the cometary energy is deposited in the atmosphere.

The second group at the 3.6-m telescope, led by Benoit Mosser from Institut d'Astrophysique, Paris, will be looking for short- and long-term oscillations of the entire planet during the days and nights following the impacts. It is agreed that such observations will not be easy, but they offer the best hope we presently have of learning about the internal structure of Jupiter. It may be deduced from the observed frequencies and modes of oscillation. A particularly interesting problem is whether Jupiter really possesses a core of metallic hydrogen, as postulated by some scientists.

Infrared images will also be made by Klaus Jockers from the Max-Planck-Institut für Aeronomie with the ESO infrared IRAC camera at the MPI/ESO 2.2-m telescope. Since they will be obtained at shorter wavelengths than those at TIMMI, they will show higher layers of the atmosphere and the possible changes (streaming motions, new whirls and eddies?) which may result from the impacts. These programmes will therefore complement each other.

A total of no less than 13 half-nights have been allocated at the 3.5-m New Technology Telescope. They will be shared between two groups which will both use the IRSPEC instrument to obtain detailed infrared spectra of the impact sites. One team is headed by Rita Schulz, the other by Thérèse Encrenaz from Observatoire de Paris. Among many others, they hope to observe some of the molecules which may be present in the deeper layers of the Jovian atmospheres, e.g., water, ammonium and phosphine (PH_3).

Altogether, there are 12 individual programmes at all of the major telescopes, including the 3.6-m, the NTT, the SEST, the 2.2-m MPI/ESO, the 1.4-m CAT and the Danish 1.54-m telescope.

The Observations Are Difficult

The observers at ESO will profit from the simultaneous observations with many different telescopes and observing techniques at one site. In particular, they will have contact with observers at the South African Astronomical Observatory (SAAO), where observations will start a few hours before each evening. They will then be able to better prepare themselves for unexpected developments, should such be observed at SAAO.

It is clear that these observations will be difficult, in particular because of the relatively short time that Jupiter and the comet will be well above the horizon at La Silla, at most a few hours each evening. When Jupiter is very low in the sky, the viewing conditions are less favourable, since the light must traverse a longer distance through the turbulent and absorbing terrestrial atmosphere. However, since Jupiter will be south of the celestial equator, observing conditions will be even worse from observatories located in the northern hemisphere.

To record the best possible data (images, spectra, light curves, etc.), the telescopes must follow the motion of Jupiter very accurately. Due to its orbital motion in the solar system, Jupiter moves rather rapidly in the sky, and the telescope motion must be precisely offset to continuously track the planet without "smearing" the images. This is not a simple task, also since the planet's rate of motion changes with time and new corrections must be made several times each hour.

All in all, the observers face a difficult task and must be extremely alert, especially around the predicted moments of impact. This will demand very high concentration and necessitate "training runs" before the real observations begin. Some of these have already taken place – not surprisingly, various technical problems were uncovered and are now in the process of being resolved.

ESO's Special Services to the Media

In view of the unique nature of this event and the associated astronomical observations, ESO has decided to provide special services to the media. In particular, it is the intention to ensure that the media will be able to follow the developments at La Silla closely and in near-real time, and at the same time will be kept informed about the observational results at other observatories all over the world.

This service will be available from the ESO Headquarters in Garching near Munich, Germany, and special arrangements are also being made for the media in Chile. It will have the following elements:

- Background material in the form of text and images, as well as related video clippings (broadcast quality) will be available at request from July 5.
- From July 11, ESO will issue daily bulletins with the latest predictions and other news, related to the preparations of observations at La Silla and elsewhere in the world.
- Press Conferences will be arranged at the ESO Headquarters in Garching and at the ESO Office in Santiago de Chile on Saturday, July 16, just before the first impacts. Following an in-depth briefing, some of the media representatives will pass the night at the ESO Headquarters from where they can follow the first observations at La Silla at distance.
- There will be a Press Conference at the ESO HQ each following day at 11:00 (CEST), summarizing the previous night's results. Selected images obtained at ESO the night before will be available on these occasions. Special arrangements are also being made for the Chilean media.

Based on ESO Press Releases 02/94 and 10/94